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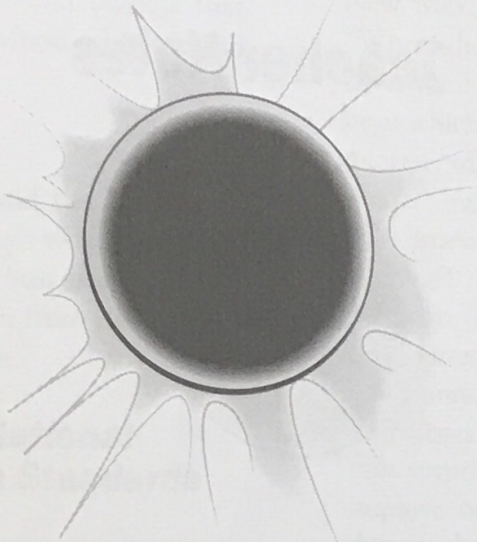
Moon Phase and Solar Eclipse



During a solar eclipse the Moon appears to completely cover the Sun. What phase is the Moon in just before and after a solar eclipse? Circle the answer that best matches your thinking.

A full Moon

B new Moon

C first quarter Moon

D last quarter Moon

E It can be in any phase.

Describe your thinking. Provide an explanation for your answer. _____

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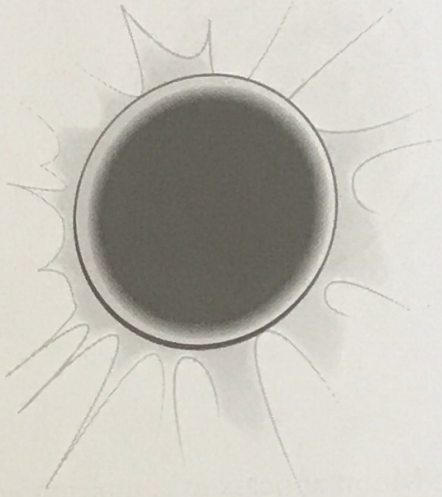
Moon Phase and Solar Eclipse

Teacher Notes



Purpose

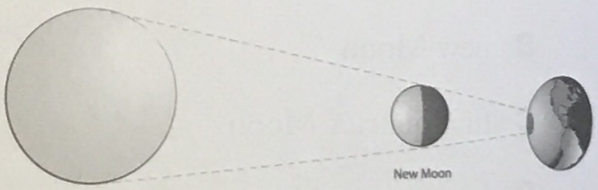
The purpose of this assessment probe is to elicit students' understanding of the Earth-Sun-Moon system well enough to explain the causes of Moon phases and solar eclipses and how these two phenomena are related.

Related Concepts

Moon: appearance, eclipse, orbit, phase
Solar system objects: orbits

Explanation

The best answer is B: new Moon. If students had an opportunity to observe and record Moon phases for a few weeks, they would see that Moon phase is correlated with the angle between the Moon and the Sun. Since the Moon must be between the Earth and the Sun for a solar eclipse to occur, the Sun must be illuminating the side of the Moon that we cannot see, which means it is in the new Moon phase. This idea is illustrated below (illustration is not to scale):



Administering the Probe

This probe is best used after middle or high school students have had the opportunity to learn about Moon phases and eclipses. The probe is a challenging question that requires students to stretch a bit to envision the relationship between Moon phases and eclipses. If necessary, show a graphic of each of the Moon phases so that the probe is not dependent on students knowing the terminology.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 2009)

3–5 The Universe

- The Earth is one of several planets that orbit the Sun, and the Moon orbits around the Earth.

6–8 The Earth

- The Moon's orbit around the Earth once in about 28 days changes what part of the Moon is lighted by the Sun and how much of that part can be seen from the Earth—the phases of the Moon.

Related Ideas in *National Science Education Standards* (NRC 1996)

5–8 Earth in the Solar System

★ Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the Moon, and eclipses.

Related Research

- Danaia and McKinnon (2007) administered tests of astronomy knowledge to 1,920 students in grades 7, 8, and 9 in Australia. One of the questions asked students for the phase of the Moon at a total solar eclipse. The correct answer, "new phase," was given by only 1% of the seventh graders and 10% of the eighth and ninth graders. About half of the students did not even attempt to answer the question.
- Several instructors of introductory college astronomy courses have used a standard test, the Astronomy Diagnostic Test (ADT), to measure the effectiveness of their teaching (Hufnagel 2001). For example, Zeilik and Morris (2003) used an early version of the ADT to evaluate a one-semester introductory course in astronomy for college freshmen at the University of New Mexico. One of the questions was: "When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase? (a) full; (b) new; (c) first quarter; (d) last quarter; (e) no particular phase." At the beginning of the course 49% knew the answer; at the end of the course 90% answered correctly.
- LoPresto (2006) used the ADT as a pre- and posttest for students in an introductory astronomy course at a community college. Test scores averaged over three years found (not surprisingly) that students tended to improve on items that were emphasized during the course. With respect to the question "When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?" the percentage of students choosing the correct answer (new) increased from an average of 12% on the pretest to 42% on the posttest.

Suggestions for Instruction and Assessment

- This probe can be combined with "Solar Eclipse" from *Uncovering Student Ideas in Science, Vol. 4: 25 New Formative Assessment Probes* (Keeley and Tugel 2009).
- Students who have memorized a basic explanation for a solar eclipse (the Moon is between the Earth and the Sun) will probably have difficulty answering this question. However, those who learned to explain both phases and eclipses using a physical model have a good chance of envisioning how the Moon would be moving in its orbit just before passing in front of the Sun, and just after the eclipse.

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

- By middle school the great majority of students will have the spatial visualization skills needed to understand solar and lunar eclipses as well as phases. However, it will be important for them to first be clear about the monthly cycle of phases, preferably through their own observations, and then to have an opportunity to model phases.
- It is best to model both phases and eclipses with a single bright bulb in a darkened room to represent the Sun and a ball for each child to hold, representing his or her personal Moon. The students can then see their model Moon go through an entire cycle of phases as they slowly move it in a circle around their heads (with their heads representing Earth). The students will observe that as the Moon gets closer and closer to the Sun it has a thinner and thinner crescent. When it is very close to the Sun it cannot be seen at all—that is the new Moon phase. On rare occasions the Moon passes directly in front of the Sun, causing a solar eclipse—but only during the new Moon phase.
- This assessment probe is a sensitive instrument to determine not only if the students can recall a definition of a solar eclipse but also if they can envision the Moon getting closer and closer to the Sun, and entering the new Moon phase, before a solar eclipse occurs. Therefore, at the high school level, it may be a good idea to have students respond to this probe before beginning a unit on astronomy. If they have difficulties with it, the activity described above that models Moon phases and eclipses will be appropriate.

References

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Keeley, P., and J. Tugel. 2009. *Uncovering student ideas in science, vol. 4: 25 new formative assessment probes.* Arlington, VA: NSTA Press.

LoPresto, M. C. 2006. Astronomy Diagnostic Test results reflect course goals and show room for improvement. *Astronomy Education Review* 5 (2): 16–20. *http://aer.aas.org/resource/1/aerscz/v5/i2/p16_s1*

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.

Zeilik, M., and V. J. Morris. 2003. An examination of misconceptions in an astronomy course for science, mathematics, and engineering majors. *Astronomy Education Review* 1 (2): 101–119.

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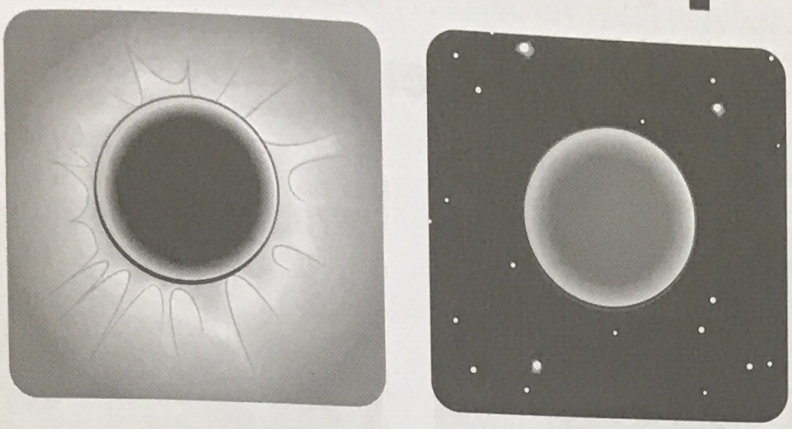
Comparing Eclipses



From any place on Earth a person can see more eclipses of the Moon than of the Sun. Why do you think this is so? Put an X in front of all the statements that support reasons why we see more lunar eclipses than solar eclipses.

_____ **A** The Sun moves more quickly than the Moon.

_____ **B** Anyone who can see the Moon when it enters Earth's shadow will see an eclipse of the Moon.

_____ **C** The shadow of the Moon on the Earth is very small and moves quickly.

_____ **D** The Moon goes in front of the Sun more often than the Sun goes in front of the Moon.

_____ **E** The Moon's orbit around the Earth is faster than Earth's orbit around the Sun.

_____ **F** The Moon spins on its axis faster than the Earth spins on its axis.

Describe your thinking. Use the ideas you marked with an X to explain why we see more lunar eclipses than solar eclipses. _____

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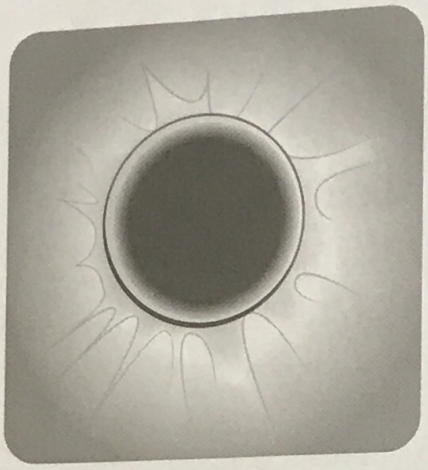
Comparing Eclipses

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about eclipse phenomena. The probe is designed to determine if students have a mental model of the Earth-Sun-Moon system that allows them to figure out why we see more eclipses of the Moon than of the Sun.

Related Concepts

Moon: appearance, eclipse, orbit, size
Sun: eclipse

Explanation

The best answers are B and C. Both are needed to answer the question: Why do we see more eclipses of the Moon than of the Sun?

An eclipse of the Moon occurs when the Moon is in full phase, at the opposite side of the sky from the Sun. About twice per year the Moon moves into the shadow of the Earth, where it darkens and often turns a dark red color. It takes several hours until the Moon emerges from Earth's shadow. Anyone on the side of the Earth that can see the darkened Moon in Earth's shadow will observe an eclipse of the Moon. Since about two eclipses of the Moon occur every year, chances are 50% that we'll be on the right side of Earth to view the eclipse of the Moon, which is why a lunar eclipse can be seen from any spot on Earth about once a year.

An eclipse of the Sun occurs when the Moon passes between the Earth and Sun. Since the Moon is much smaller than the Earth, its shadow is also much smaller—only about 100 miles wide when it sweeps across the Earth. The only people who can see an eclipse of the Sun are those who are in the path of the Moon's shadow, which is why an eclipse of the Sun is seen only rarely from any given spot on the Earth.

Administering the Probe

This is a challenging probe, most appropriate for high school students, although middle school students who fully understand phases of the Sun and the Moon may be able to answer the probe's question. The probe would be most effectively used *after* a unit in which students learn about eclipses of the Sun and the Moon, to encourage them to envision and compare both types of eclipses. This probe can be used to help students construct and evaluate evidence necessary for scientific explanations. Encourage students to work in small groups to examine and critique each statement and decide whether or not it can be used to support an explanation for why we see more lunar eclipses than solar eclipses.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 2009)

3–5 The Universe

- The Earth is one of several planets that orbit the Sun, and the Moon orbits around the Earth.

Related Ideas in *National Science Education Standards* (NRC 1996)

5–8 Earth in the Solar System

★ Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the Moon, and eclipses.

Related Research

- Callison and Wright (1993) taught a unit on astronomy to college students preparing to become elementary teachers. To evaluate the effectiveness of their course, the researchers interviewed some of the students before and after instruction. They found that "conceptual growth occurs over time and requires revising and reflection." They also cautioned teachers to "beware of false positives," which are "responses that sound correct on the surface yet supported with incorrect notions. During the interview process the interviewer heard the 'right' words. However, once the subjects were questioned about the meaning of those 'right' words, the meaning was absent or incomplete." As an example, consider the following dialogue about Moon phases and eclipses between the interviewer (I) and a student (S):

I: What is your explanation for why the phases of the Moon occur?
S: Because the Moon is moving around the Earth and the Earth is rotating and the Moon gets light from the Sun. ... The phases occur because of what we can see from Earth of the Moon moving around the Earth.
I: If that is the case, would there be any time when the Earth was in between the Sun and the Moon? I would think it would cast a shadow on the Moon.
S: That would be an eclipse.
I: [In an attempt to get the subject to review her thinking]: So if the Earth is between the Moon and the Sun, what phase of the Moon do we see on Earth?
S: Dark.
I: So are you saying it is an eclipse?

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

S: Well, no, because an eclipse doesn't happen that often. I don't understand why an eclipse only happens every once in a while. It has just got to be on the correct axis or something. I don't know.

- Students' understanding of eclipse phenomena may be related to their lack of understanding of the relative sizes of the Sun, the Moon, and the Earth and the great distances between these bodies. Many students draw these objects so they are the same size or between half and double each other's size. They also draw the Sun and the Moon within one to four Earth diameters away from the Earth (Driver et al. 1994).

Suggestions for Instruction and Assessment

- This probe can be combined with the "Lunar Eclipse" and "Solar Eclipse" probes in *Uncovering Student Ideas in Science, Vol. 4: 25 New Formative Assessment Probes* (Keeley and Tugel 2009).
- Although middle school students can learn to explain Moon phases and eclipses of the Sun and the Moon, questions such as this one are very challenging and could perhaps be considered "stretch goals" for some students.
- The best way to explain why we see very few eclipses of the Sun is to have students stand in a circle around a single bright light in a darkened room and to hold a small ball representing the Moon at arm's length. The lightbulb represents the Sun and the students' heads represent the Earth. When the students hold the Moon ball in front of them so it covers the bright bulb, ask the students to glance around the room and see that everyone has a circular shadow over their eyes. Ask: Would everyone in the shadow see an eclipse of the Sun now? (Yes.) How about people not in the shadow, say those who "live" on your chin, cheek, or ear? (No.) Tell the students that the shadow of the real Sun on Earth during an eclipse of the Sun is just about 100 miles wide. So very few people get to see a solar eclipse, even though about two eclipses of the Sun occur every year. To see more eclipses it is necessary to travel to a place where the Moon's shadow will sweep across the Earth and hope that it will be a clear day.
- To explain why we can see about one eclipse of the Moon every year, have the students in the above demonstration move their Moon ball around to the full Moon position, so it is opposite the Sun bulb. Now have them pass the Moon into the shadow of their heads, noticing the shape of their head as they do so. Explain that at this point the Moon usually glows dull red and it is several hours before the Moon emerges from the shadow. Ask: Can everyone "living" on your face now see an eclipse of the Moon (Yes.) How about people "living" on the back of your head? (No. They cannot see the Moon now.) Explain that eclipses of the Moon occur about twice per year, and since there is a 50-50 chance of being on the right side of the Earth when it occurs, we usually have a chance to see an eclipse of the Moon about once a year.
- It is important for students to have a solid grasp of the Earth-Sun-Moon system by the time they reach high school and study more complex topics involving Earth's relationship to other bodies. This probe can be used to diagnose high school students' understanding of eclipses. If the students struggle with the answer, you may want to do the activity described above.

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